DISTRIBUTION OF THE ENERGY IN THE SHORTWAVE REGION OF THE SPECTRUM FOR VARIOUS PARTS OF SATURN'S DISK[2]

V. D. Krugov

ABSTRACT. The results are presented of measuring ultraviolet absorption for Saturn's disk in a range of 3300 - 4800 Å taken in 1968 - 1969. The observations were carried out with the 70-cm reflector and spectrograph ASP-7 (dispersion 230 Å/mm at H and K). It is found out that the quantity of ultraviolet absorption for various regions of Saturn's disk (equator, meridian, the southern polar region, eastern and western limbs) is lg I(0.33) - lg I(0.48) = 0.30 on the average. Time variations are observed in the course of reflectivity for various regions of Saturn's disk. The data for the rings show a more neutral motion of albedo along the spectrum and time variations are shown rather less.

Virtually no study has been made as yet of the relative spectral energy /23 distribution for different regions of Saturn's disk, and this is, to some degree, associated with the presence of a ring around the planet's disk. Nevertheless, such investigations, as those of Jupiter, are of great interest.

We began to study the relative spectral energy distribution for different regions of Saturn's disk in the 3300-4800 Å range with a 70-cm reflector and ASP-7 spectrograph at the Main Astronomical Observatory of the Academy of Sciences of the Ukrainian SSR, in August 1968. The slit in the spectrograph measured 0.18 mm, and the MF-4 window cut out a section $\Delta\lambda \sim 12$ Å/mm near the H and K lines on the spectrogram. Figure 1 shows the position of the slit on Saturn's disk and ring. The spectrograph slit was at a distance of $r \approx 0.6Rc$ in order to reduce the influence of atmospheric dispersion during the study of the south polar region. The height of the microphotometer window when measuring the corresponding spectrograms was selected with the considerations cited in the paper on the spectrophotometry of Jupiter's south polar region in mind.[3] The star ξ^2 Ceti, of spectral class AO, and at the same zenith distance as the

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2. Figures 6-9 are appendices and illustrate the relative spectral energy distribution for different regions of Saturn.

3. V. D. Krugov, "Ultraviolet Absorption in the Continuous Spectrum of Jupiter." This collection, p. 9.

planet, was observed for purposes of standardization and to exclude the influence of extinction. The procedures used for the observations, and for processing the spectrograms, were those used for Jupiter.

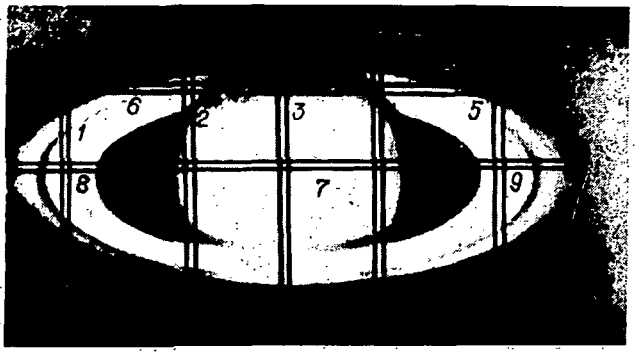

Figure 1. Position of spectrograph slit on Saturn's disk (6 - south polar region).

A total of 300 spectrograms of Saturn and of the comparison star were obtained between 5 August 1968 and 21 November 1969, and 100 were processed for different regions of the planet's disk and ring. The relative spectral energy distribution for Saturn's disk and ring can be given by the magnitudes $\lg I_J/\lg I_\odot$.

Measurement results are listed in the table, and in the appendix. The first column lists the numbers of the regions of the planet's disk corresponding to those in Figure 1; that is, 1, 8 are the ring's west eye, 2 is the west limb, 3 is the central meridian, 4 is the east limb, 5, 9 are the ring's east eye, 6 is the south polar region, and 7 is the planet's equator. The second column is universal time for the midpoint in the interval of observations for each region. The values of $10^2[\lg I(\lambda) - \lg I(0.48)]$ are given every 100 Å for each wavelength. Unsigned values are negative.

The shapes of the relative energy distribution curves for the observed regions of Saturn's ring and disk are shown in the appendix (see Figures 6-9).

RESULTS OF MEASUREMENTS OF ENERGY DISTRIBUTION IN THE CONTINUOUS SPECTRUM OF SATURN

Disk region no.	UT	λ, microns															
		0.33	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48
								1968, 5. IX									
2	21h18m	14	12	18	06	25	27	26	30	28	20	16	08	08	06	03	0
3	22 24	27	23	30	38	39	40	35	35	30	23	20	14	11	10	05	0
4	23 37	57	52	55	49	47	50	43	36	26	20	16	11	10	02	08	0
								7. IX									
2	21 08	52	55	48	41	44	52	47	37	31	21	14	08	05	03	04	0
3	22 18	46	44	47	47	33	45	42	38	35	26	30	17	08	05	02	0
4	23 24	56	52	56	54	54	48	42	32	27	24	19	13	07	06	04	0
								9. IX									
2	22 18	48	42	45	42	38	39	32	30	25	19	13	06	01	02	02	0
3	23 19	50	44	42	44	40	43	39	35	28	22	17	10	03	05	05	0
4	0 22	47	48	46	43	47	58	49	43	35	37	16	11	05	04	05	0
								9. X									
2	22 00	37	37	37	36	36	43	42	33	27	22	13	11	07	06	06	0
3	23 07	37	37	37	42	43	51	43	30	24	20	16	04	05	06	06	0
								10. X									
2	20 45	34	34	31	40	49	49	49	37	32	26	20	13	08	06	07	0
3	21 41	21	25	24	31	35	47	35	23	20	19	12	11	11	08	06	0
4	19 49	07	01	07	07	06	12	28	17	17	13	10	05	01	02	05	0
								30. X									
2	19 22	48	43	41	36	40	45	31	27	24	16	11	10	09	06	04	0
3	20 20	07	08	09	07	21	17	16	07	10	05	05	07	05	06	04	0
4	21 11	36	35	35	35	28	35	23	24	18	12	09	09	08	05	02	0
								24. XI									
2	17 00	44	41	40	41	43	51	48	36	35	28	21	12	08	08	02	0
3	17 44	35	25	25	34	34	34	33	24	19	16	09	03	06	05	03	0
4	18 25	13	13	25	17	20	23	26	20	15	11	10	13	11	10	09	0

Disk region no.	UT	λ, microns															
		0.33	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48
								1968, 13. XII									
1	19h40m	29	26	26	15	25	17	09	05	08	11	13	10	11	09	06	0
2	18 00	70	56	56	56	59	54	44	37	32	31	23	24	10	07	07	0
3	18 29	69	59	56	53	55	49	43	34	38	28	25	17	07	04	01	0
4	18 51	52	58	41	39	52	50	41	36	34	29	25	16	10	10	05	0
5	20 10	15	11	06	02	03	17	33	10	07	06	09	12	11	12	05	0
6	16 42	40	41	38	38	40	31	25	25	25	24	14	12	03	07	06	0
								15. XII									
1	16 19	38	31	29	19	21	20	09	03	02	00	+03	+03	+04	+03	+01	0
								1969, 4. I									
1	16 20	55	53	53	48	44	48	44	37	34	32	26	15	09	07	04	0
5	17 14	63	63	55	50	47	44	44	38	37	31	23	19	13	07	02	0
6	18 06	35	30	23	31	34	27	25	28	24	21	14	+03	00	00	+07	0
								5. I									
1	15 06	46	53	44	34	27	27	29	19	18	13	14	06	01	+02	01	0
2	15 50	64	47	53	57	56	48	33	57	43	32	31	22	16	10	06	0
3	16 31	49	43	49	44	52	43	45	34	24	26	24	14	06	01	00	0
4	16 21	54	55	45	52	50	65	46	38	31	31	26	19	13	12	08	0
5	15 38	54	50	54	50	42	23	36	42	26	21	16	17	07	06	04	0
6	17 04	55	66	57	45	50	53	51	40	35	31	23	11	07	07	04	0
								6. I									
2	18 39	37	42	43	44	42	36	46	34	39	28	24	19	07	08	05	0
4	19 18	63	53	45	49	51	55	42	38	33	29	20	08	+03	+02	+05	0
								30. VIII									
1	23 27	37	34	30	29	29	14	04	07	08	07	05	02	+01	+01	+01	0
5	0 17	30	24	23	20	25	09	04	08	09	05	02	01	+02	+01	+02	0
								31. VIII									
3	0 31	33	31	33	33	37	22	22	20	19	16	12	07	01	00	01	0
								7. IX									
1	23 38	42	42	37	40	28	30	27	19	20	19	17	11	08	06	+01	0
5	23 48	42	28	27	10	16	14	11	14	24	03	+03	+05	+04	00	+01	0

Disk region no.	UT	λ, microns															
		0.33	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48
								1969, 8. IX									
1	2h40m	50	38	37	34	28	24	37	21	26	22	18	13	11	09	09	0
3	21 47	19	25	35	35	41	30	35	27	21	22	14	07	04	09	08	0
								10. IX									
3	21 53	44	47	53	55	56	46	30	20	17	02	02	05	02	04	07	0
6	21 30	+05	+10	04	02	11	00	00	+08	00	+06	+04	+08	+10	+04	+07	0
7	21 40	10	22	22	26	33	11	17	15	20	13	07	+03	+08	+04	03	0
8	21 40	04	02	03	+02	08	09	+11	02	13	07	00	+12	+02	03	07	0
9	21 40	+13	+13	+08	+08	+11	+10	+12	+07	00	+03	+26	+13	+05	03	08	0
								11. IX									
2	23 58	39	36	34	38	37	28	27	20	22	14	10	07	+05	+02	+02	0
4	0 06	47	45	47	51	47	45	39	32	30	29	23	19	08	09	11	0
5	23 00	58	45	36	31	25	30	20	14	21	12	00	+04	00	03	03	0
								24. IX									
1	22 23	46	41	38	36	27	23	15	13	09	04	05	+01	+03	+02	+01	0
2	1 53	23	15	13	15	18	26	21	12	09	04	00	02	01	03	02	0
3	1 46	45	33	33	38	34	32	26	24	26	18	11	06	02	02	00	0
4	1 40	25	25	25	25	28	22	23	12	16	10	07	03	00	02	01	0
5	22 33	25	28	33	21	15	14	13	07	00	01	00	02	+01	01	01	0
6	21 20	07	07	11	18	16	16	13	08	12	04	10	05	00	02	04	0
7	21 33	02	11	09	18	24	18	27	17	18	15	15	13	06	08	05	0
								27. IX									
6	20 01	27	33	34	34	37	33	24	19	13	13	16	08	05	00	02	0
7	20 36	31	34	28	37	33	40	34	28	28	17	17	10	03	02	02	0
8	20 36	22	18	20	19	07	14	04	03	00	02	01	00	+02	+01	+02	0
9	20 36	28	26	22	14	08	14	12	05	06	05	05	04	02	03	02	0

Disk region no.	UT	λ, microns															
		0.33	.34	.35	.36	.37	.38	.39	.40	.41	.42	.43	.44	.45	.46	.47	.48
								13. X									
1	19h16m	37	31	20	27	19	13	08	19	15	13	11	09	00	01	01	0
2	19 41	00	+05	+08	+08	+13	+08	+12	+09	+09	+04	00	+01	+04	00	+02	0
3	20 06	+02	+02	08	14	17	15	08	06	04	+01	+01	+02	+04	+02	+03	0
4	20 34	16	24	25	24	25	32	18	24	17	16	10	08	00	01	10	0
5	20 59	+03	+16	+15	+18	+13	+16	+23	+17	+14	+00	+01	+02	+02	+00	00	0
6	21 24	08	04	09	00	+01	00	+06	+09	+06	+08	+06	+04	+07	+04	+06	0
7	21 49	41	33	34	34	34	41	27	30	25	19	19	06	+01	+04	+03	0
8	21 49	42	30	26	20	22	24	+03	11	12	09	09	02	+03	+02	+01	0
9	21 49	50	51	41	29	24	31	13	16	08	10	10	03	+04	+06	+01	0
								14. X									
7	22 43	21	11	10	14	16	15	12	08	04	+01	+02	+03	+04	+02	+02	0
8	22 43	21	12	16	09	12	11	00	00	01	01	+02	+04	+05	+04	+03	0
9	22 43	30	21	20	14	13	07	03	+12	+03	+05	+07	+06	+05	+05	+04	0
								15. X									
1	23 30	08	03	00	+07	+03	+09	+12	+14	+11	+09	+07	+05	+04	+03	+02	0
2	21 03	05	+04	02	00	+03	+11	+05	+08	+09	+08	+09	+08	+06	+04	+03	0
3	21 25	13	02	12	10	09	07	01	06	06	04	01	+01	+01	00	+01	0
4	21 50	08	20	07	02	10	00	+02	+01	+04	+04	+03	+01	+01	00	+02	0
6	19 21	17	09	08	07	12	13	07	01	+01	+04	+06	+08	+07	+05	+02	0
7	19 53	07	01	11	18	19	10	10	11	10	07	04	02	+01	+01	+03	0
								16. X									
7	20 58	31	26	26	25	29	28	25	21	15	14	11	06	01	02	00	0
8	20 58	28	24	16	17	08	06	02	+04	+04	+01	+01	00	+03	00	+02	0
9	20 58	23	16	16	10	14	09	02	+01	00	01	+01	+01	+04	+02	+02	0
								21. X									
1	21 25	02	02	01	+03	+02	+12	+12	+11	+11	+07	+01	+01	02	04	05	0
2	20 10	21	22	23	27	34	30	24	19	17	12	06	02	+03	+04	+03	0
3	21 47	56	51	53	52	54	51	39	32	26	18	12	04	01	+01	00	0
4	22 35	23	22	25	21	27	27	24	12	14	12	08	02	+02	+03	+06	0
5	23 05	07	07	11	07	07	03	+19	+06	+02	+01	+02	03	04	06	06	0
6	19 43	29	29	38	29	27	24	20	15	12	07	04	01	+01	+02	+07	0
7	19 10	37	45	48	47	50	45	41	43	37	26	20	16	07	02	09	0
8	19 10	42	36	35	29	29	18	19	18	17	+01	01	01	+03	+04	00	0
9	19 10	44	34	27	28	32	28	23	21	18	08	05	05	01	+01	+01	0

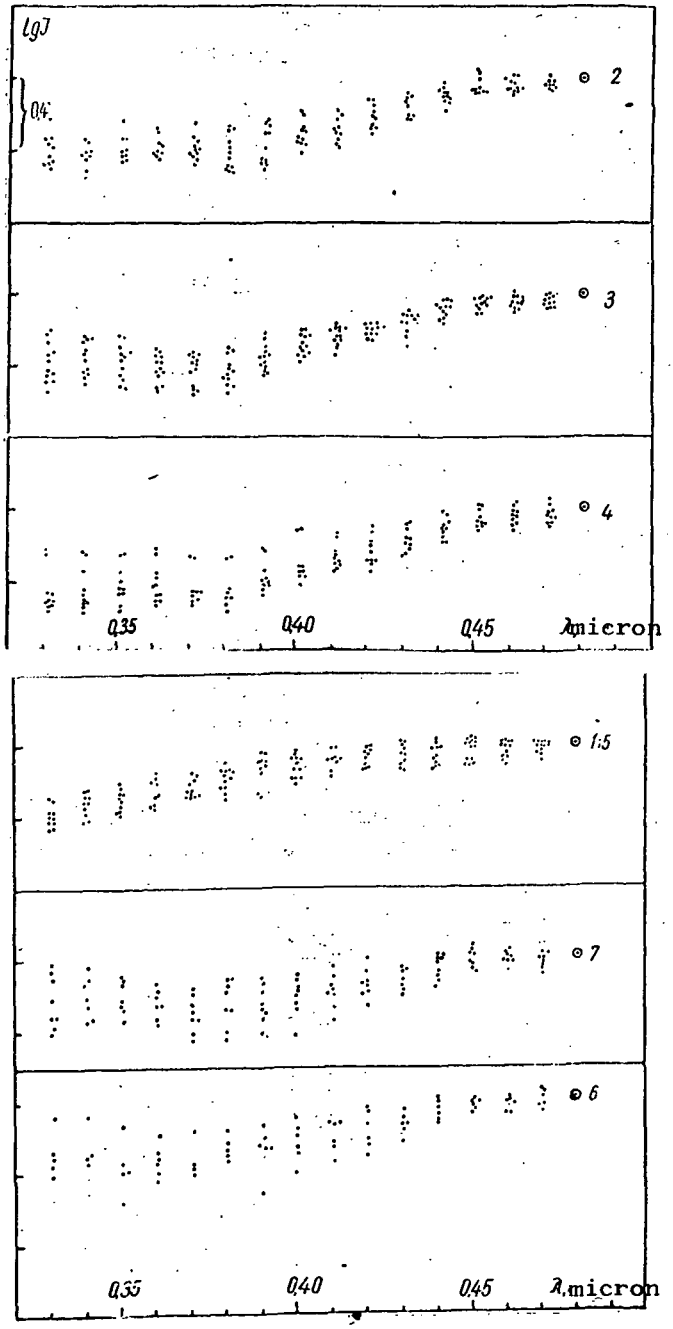

Figure 2. Relative energy distribution in different regions of Saturn's disk (composite data): 1 and 5 are the ring.

Figure 2 shows composite data on the relative spectral energy distribution /29 for each region of Saturn's disk and ring for the entire observation period. These graphics are a visual display of the difference in the behavior of the reflectivity between regions of Saturn's disk and ring for individual observation dates. It has been assumed that the time-dependent relative spectral energy distribution for the ring is constant. This fact is at the basis of determinations made of the errors in spectral energy distribution for different regions of Saturn's disk and ring. Eight spectrograms of the east and west eyes of the ring were obtained within 40 minutes on 27 September 1969, near Saturn's culmination in order to determine the errors. Sixteen spectrograms of the comparison star were obtained at the same time. Figure 3 I is the mean spectral energy distribution curve for the ring, from the 16 spectrograms. The vertical segments show the root-mean-square error of one measurement (5 percent). Figure 3 II is the scatter in the $\lg I(\lambda) - \lg I(0.48)$ values and gives some idea of the error in the behavior of the relative spectral energy distribution for Saturn and the ring (observation errors). Figure 4 I shows data for the planet's equator and ring, obtained simultaneously for the same position of the slit (measurements were made from details on the same spectrogram). Figure 5 I shows the mean relative spectral energy distribution curves for Saturn's equator and ring. What follows from Figure 5 I is that the magnitude of the UV absorption is the same, on the average, within the limits of observation error, for the equator and for the ring, $\lg \bar{I}(0.33) - \lg \bar{I}(0.48) \approx -0.30$. There are significant differences in the behavior of the reflectivity for equator and ring, however. The magnitude of the absorption for the equator drops sharply, beginning at λ 4500 Å, with the minimum near λ 3800 Å. The corresponding magnitude of the absorption in this band of wavelengths is -0.36. The peculiarity noted in the spectral behavior of reflectivity for Saturn's equator extends to other regions of the planet's disk as well. The magnitude of the UV absorption for the latter differ little from data for the equator.

The spectral energy distribution curve for the ring subsides monotonically to λ = 3300 Å, and there is no minimum in the λ = 3800 Å region. The behavior of the reflectivity of Saturn's rings is, overall, more neutral.

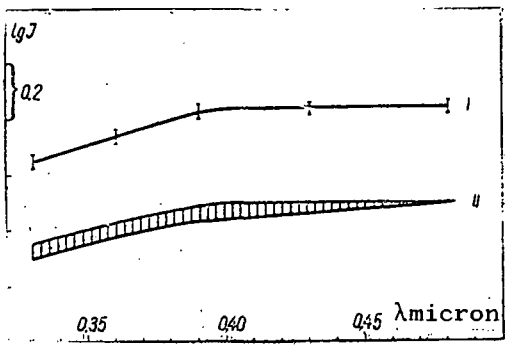

Figure 3. Relative spectral energy distribution for the ring.
I - root-mean-square error for one measurement;
II - observation error for 16 spectrograms.

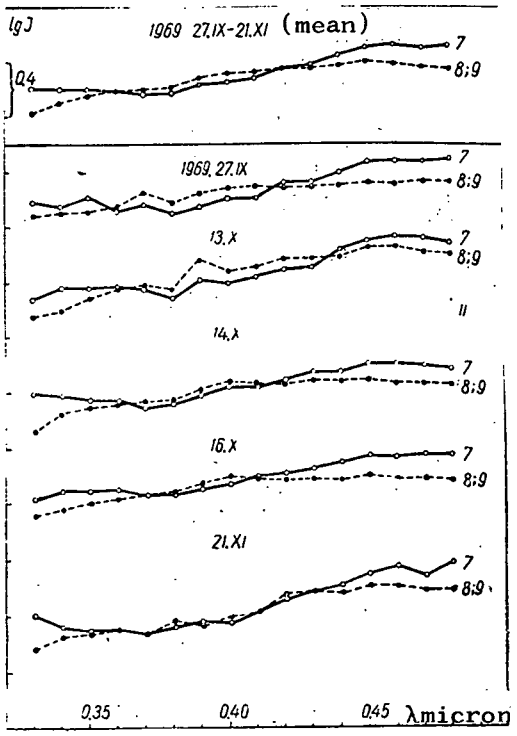

Figure 4. Spectral energy distribution for planet's equator and ring. I - mean curves; II - energy distribution for regions; 7, 8, 9 - for different observation dates.

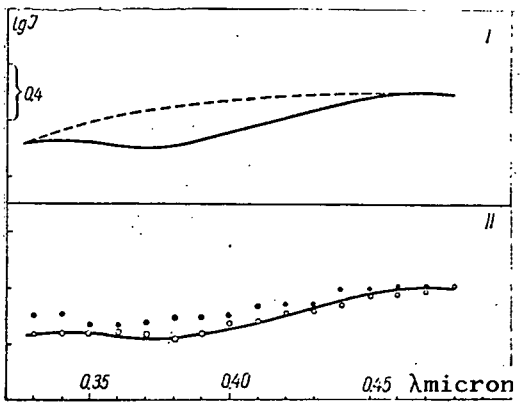

Figure 5. Reflectivity curves for the planet's equator and ring, reduced to 4800 Å. I - ring and equator comparison, ---- ring, —— equator; II - comparison of data obtained by different authors (with our results, given for the planet's equator); • - Irvine's data; o - Isakson's data; —— Krugov's data.

The curves in Figures 6-9 and 2 show that the variation in the observed relative energy distribution in the shortwave region of Saturn's spectrum is greatly in excess of the observation error. On 15 October 1969 (Figures 2, 2; 3; 4; 6; 7) lg I(0.33) - lg I(0.48) $\approx$ -0.20, whereas the difference was a mean of $\approx$ -0.50 for the other dates. As should have been expected, the temporal variations in the behavior of the spectral reflectivity for the rings were much smaller than for the planetary disk region (Figures 2, 1; 5), although there were occasional cases when these variations exceeded the observation errors noted. /30

Let us, in conclusion, compare our results with those obtained by other authors (Figure 5, II). Irvine [1] and Isakson [2] made photoelectric studies of the reflectivity of the whole of Saturn's disk between 1963 and 1965. The effect of the ring was not included. Our results (Figure 2 7) agree well with Isakson's results, but differ somewhat from Irvine's, the result, apparently, of the fact that the ring makes a definite contribution to the reflectivity of the planet's disk. The ring, as a whole, is more neutral than the planet's disk (Figures 4 and 5 I). We should point out that Isakson's period of observations coincide with small ring openings, and it is to this that its minor contribution during the observation interval can be attributed.

V. G. Teyfel' [3] made the first experiments to study the spectra of individual details in 1957. He established in particular that in the red the center of the planet's disk is much brighter than the ring, and that in the violet the ring and disk have almost the same brightness. Our results are in good concordance with his data (Figure 4 I and II).

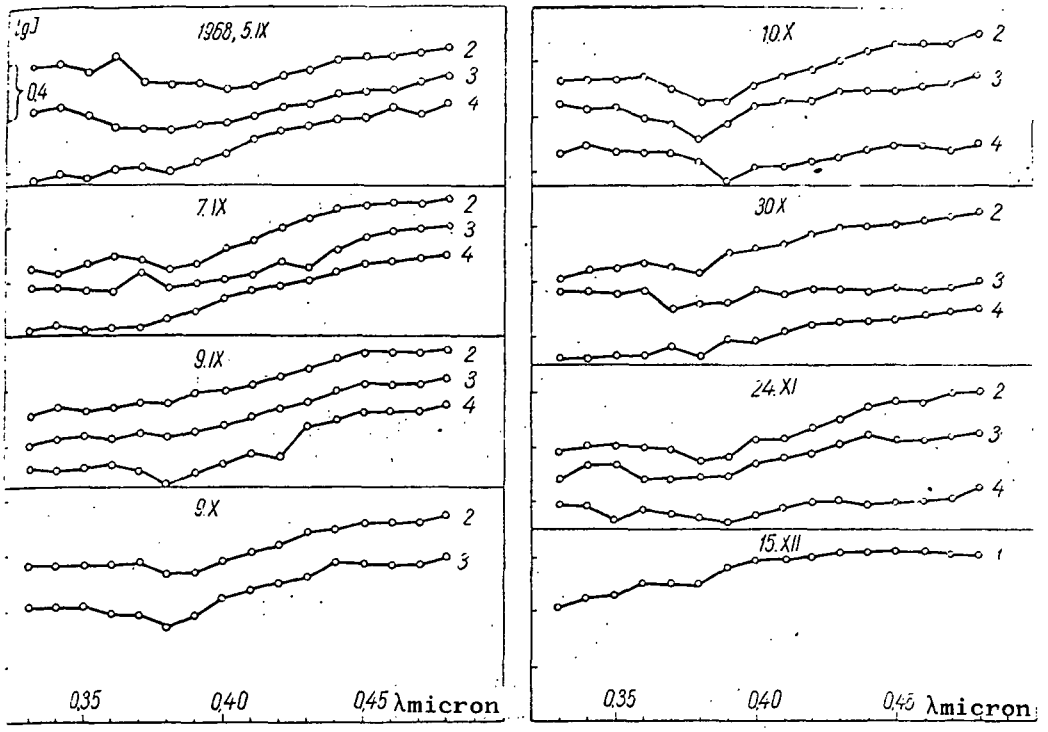

Figure 6.

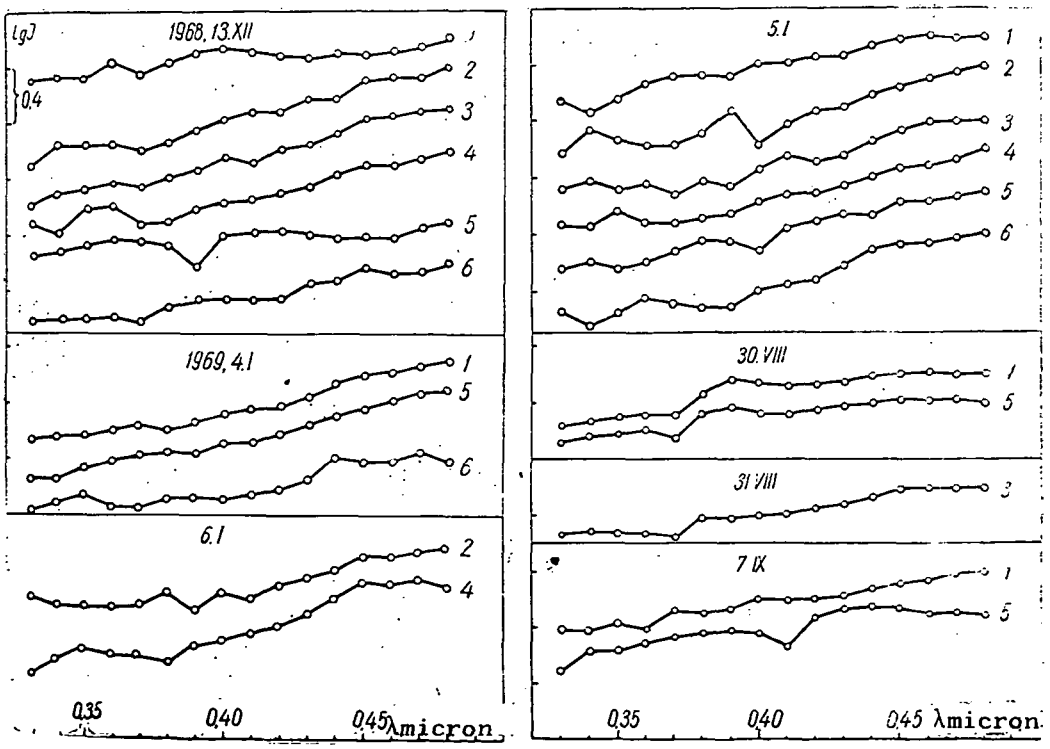

Figure 7.

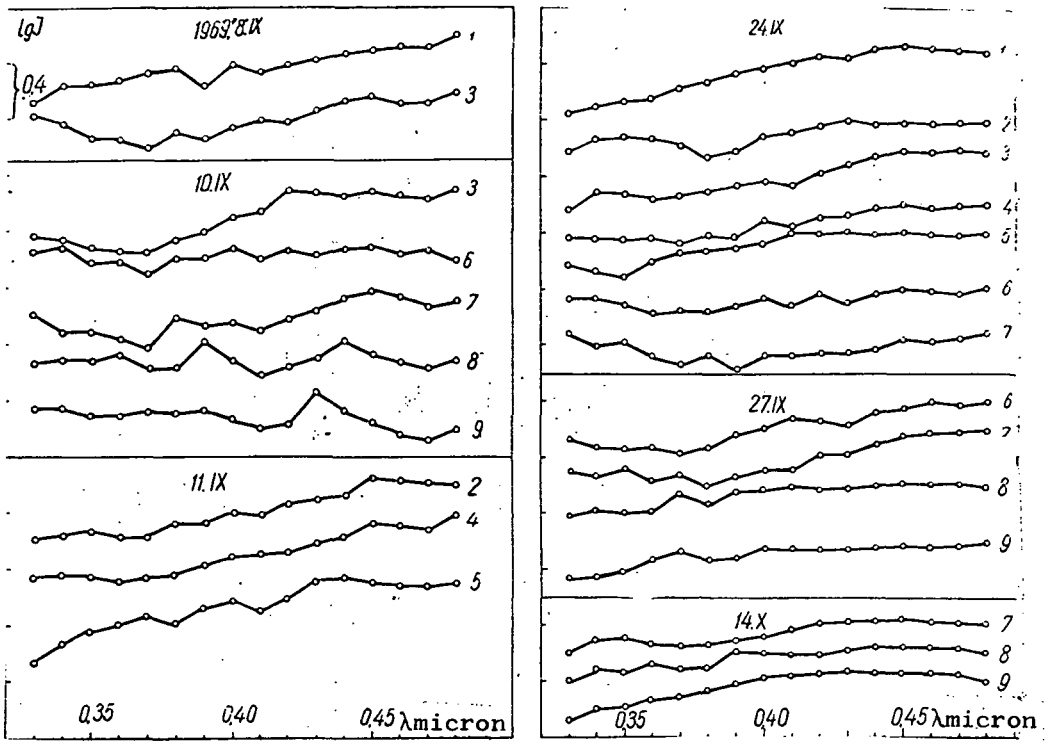

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Figure 8.

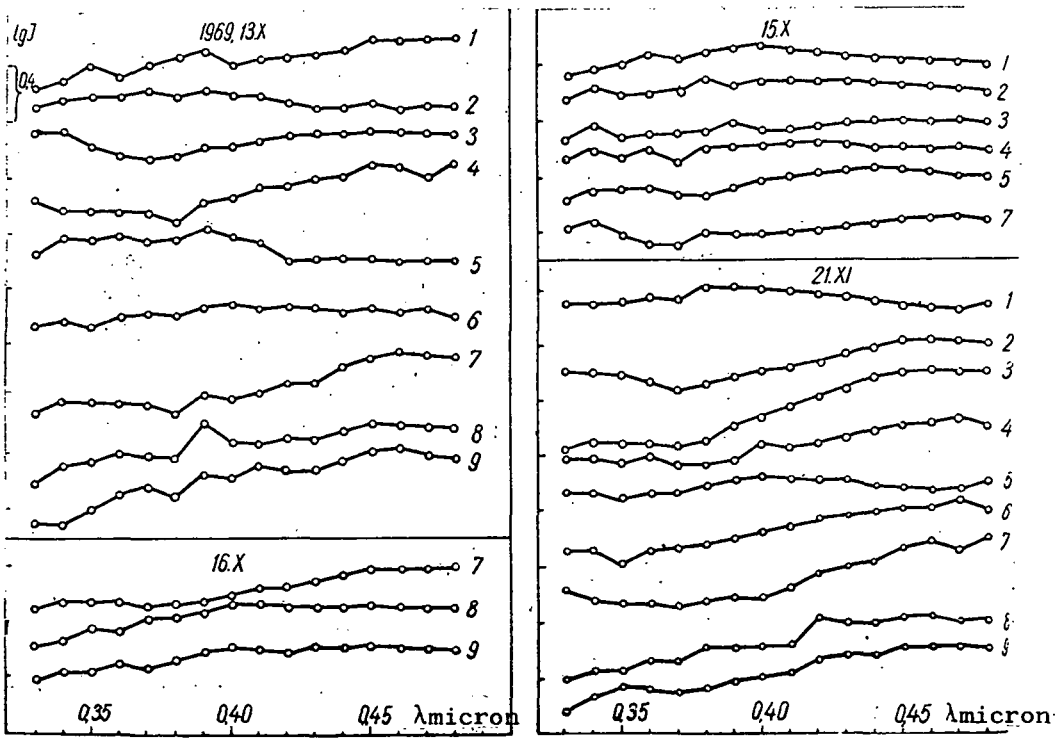

Figure 9.

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